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TECHNICAL REPORT NO. 67-51

LONG-PERIOD SEISMOGRAPH DEVELOPMENT

Quarterly Report No. 4, Project VT/6706

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GEOTECH

A TELEDYNE COMPANY

TECHNICAL REPORT NO. 67-51

LONG-PERIOD SEISMOGRAPH DEVELOPMENT

Quarterly Report No. 4, Project VT/6706

by

D. B. Andrew
B. M. Kirkpatrick

Sponsored by

Advanced Research Projects Agency
Nuclear Test Detection Office
ARPA Order No. 624

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GEOTECH
A TELEDYNE COMPANY
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Garland, Texas

28 August 1967

IDENTIFICATION

AFTAC Project No:	VELA T/6706
Project Title:	Long-Period Seismograph Development
ARPA Order No:	624
ARPA Program Code No:	6F10
Name of Contractor:	Geotech, A Teledyne Company Garland, Texas
Date of Contract:	15 June 1966
Amount of Contract:	$172,800
Contract Number:	AF 33(657)-16406
Program Manager:	David B. Andrew BR 1-2561, Area Code 214

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ILLUSTRATIONS

ILLUSTRATIONS, Continued

ABSTRACT

Development of the long-period triaxial seismometer and laboratory testing of its characteristics is essentially complete. Manufacturing changes in the mass-lock and period-adjust mechanisms are required before they can be assembled on the seismometer for laboratory and field tests of the instrument. Shake-table frequency response, the effect of temperature changes on mass position, and the effect of instrument tilt on the mass position and free period are reported.

LONG-PERIOD SEISMOGRAPH DEVELOPMENT

1. INTRODUCTION

This report describes the work performed by Geotech, A Teledyne Company, in accordance with the Statement of Work to be Done in AFTAC Project Authorization No. VELA T/6706, dated 11 March 1966. The project is under the technical direction of the Air Force Technical Applications Center (AFTAC) and the overall direction of the Advanced Research Projects Agency (ARPA).

The report discusses the progress made on the development of a long-period (LP) triaxial seismograph during the time period 1 April to 30 June 1967 and deals mainly with design concepts, instrument tests, handling equipment, and the schedule for future field evaluation of the instrumentation.

2. DEVELOPMENT OF A LONG-PERIOD TRIAXIAL BOREHOLE SEISMOMETER, TASK 1b

2.1 GENERAL

Development of the experimental LP triaxial seismometer is essentially complete. Some minor manufacturing changes are required before the improved mass-lock and period-adjust mechanisms can be assembled. After these changes are incorporated, it will be possible to begin laboratory and field tests of a completely assembled module as part of an LP seismograph.

2.2 STATUS OF THE DEVELOPMENT

Figure 1 shows one module of the triaxial seismometer at a time during its assembly which corresponds to the end of this reporting period. The module has a fully operational sensitive element and is shown, without its Randolite case, as it was being prepared for lowering into a 50 ft deep test hole at Geotech's, Garland, Texas, plant. The module is not fitted with the complete mass-locking mechanism because finished parts were unavailable. The complete triaxial seismometer has three seismometer modules, two holelocks, and a switch unit. Adapter rings are used to connect these units together in a stack. The overall design of the system permits a single module to be operated independently of the others.

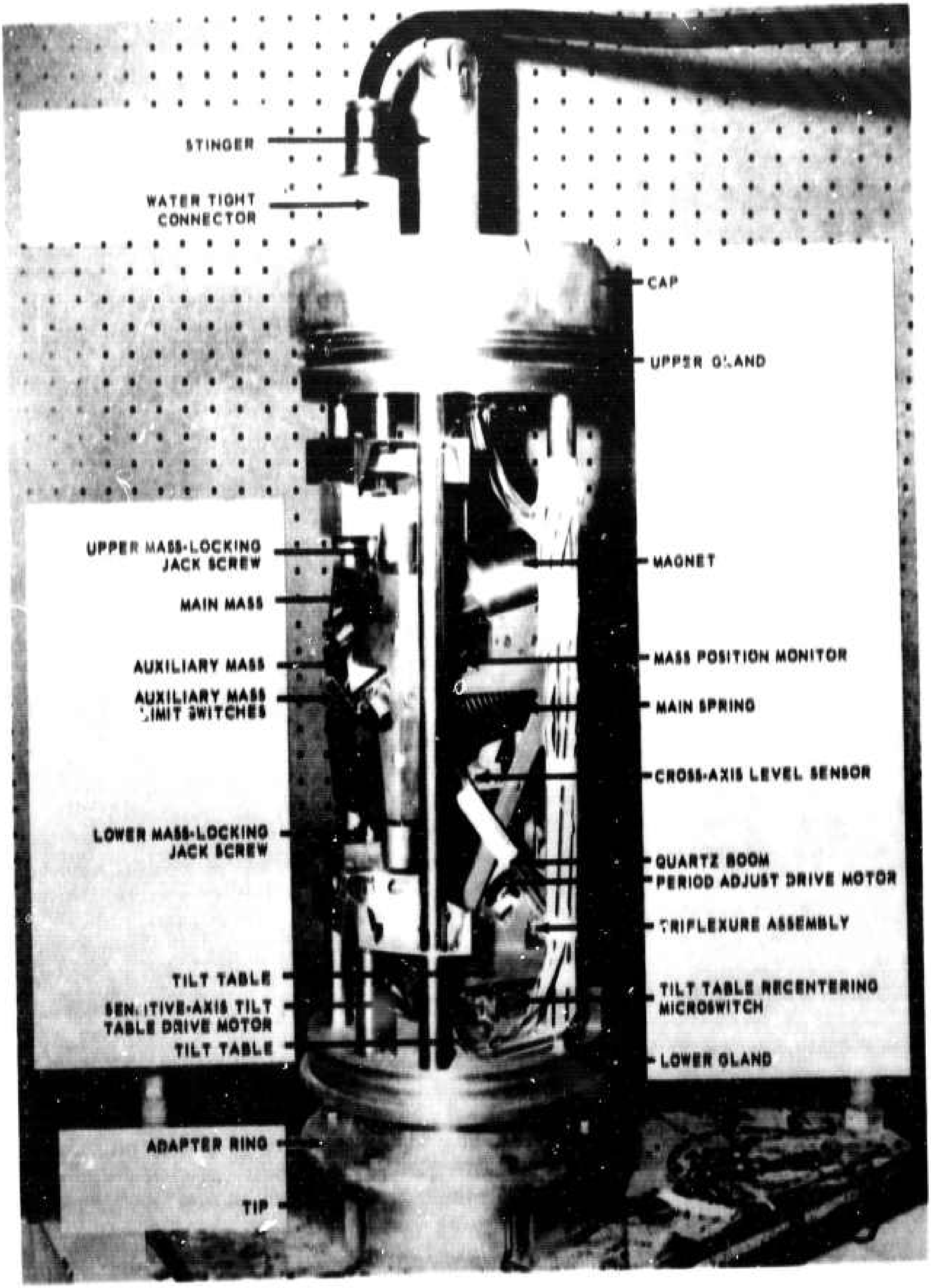

Figure 1. Partially assembled seismometer module as prepared for test in 50 ft deep hole

G 3091

2.2.1 Remote Leveling

A motor-driven two axis tilt table is used to automatically erect each sensitive element to the vertical position. This table is pointed out in figure 1 and has been described in earlier quarterly reports.

The tilt table automatically levels in both the cross-axis and the sensitive-axis planes under control of level sensors. When the module leveling circuit is electrically activated, and if the module is not already at vertical reference, the tilt table motors automatically operate until the sensitive element approaches the vertical reference in both the cross and sensitive-axis planes.

The cross axis levels to within 7 arc minutes under control of gravity sensing mercury switches. The sensitive axis must be leveled to a much higher precision than that which can be obtained from the mercury switches. Since the ultimate purpose of the leveling operation is to erect the sensitive element to its operating position with the mass floating between the mass stops, the mass-position monitor can be used to make the sensitive element the level sensor in the sensitive-axis plane. Leveling in the sensitive-axis plane is, therefore, accomplished by feeding the output of the mass-position monitor bridge circuit into a sensitive polarized relay. When the bridge is unbalanced (mass located more than 3 mm off center) its output operates the relay to control the direction of rotation of the sensitive axis tilt table motor. The assembly is designed to position the mass on the side of center opposite that indicated by the mass-position monitor. Therefore, the sensitive-axis tilt table will "hunt" and the mass will continue to oscillate from stop to stop until power to the tilt table motors is turned off. The table is then level to within 15 arc seconds in the sensitive-axis plane and the mass can be centered by an auxiliary mass adjustment (section 2.2.2).

2.2.2 Mass Position

Each seismometer module is equipped with a device (see figure 2) to remotely center the inertial mass between its limit stops. The device, which consists of a motor-positioned auxiliary mass, is located on the main mass assembly as shown in figure 1. The auxiliary mass weighs 0.55 kg (1.2 lb) and is translated in the plane formed by the axes of the two quartz booms. Translation of the auxiliary mass shifts the center of gravity of the 10 kg (22.05 lb) inertial mass. The auxiliary mass has a total travel of 7 mm and is limited at each extreme by Microswitches which interrupt the mass-position motor circuit. The auxiliary mass moves at approximately 0.2 mm/sec and thus covers its entire range in about 30 sec. Auxiliary mass movement, toward or away from the triflexure axis (see section 2.2.3), lengthens or shortens the inertial mass moment arm; therefore, the resultant torque which supports the mass is either decreased or increased and the mass position is altered accordingly. The device has been completely tested in the laboratory and will center the mass under all operating conditions after the seismometer module has been leveled as described in section 2.2.1.

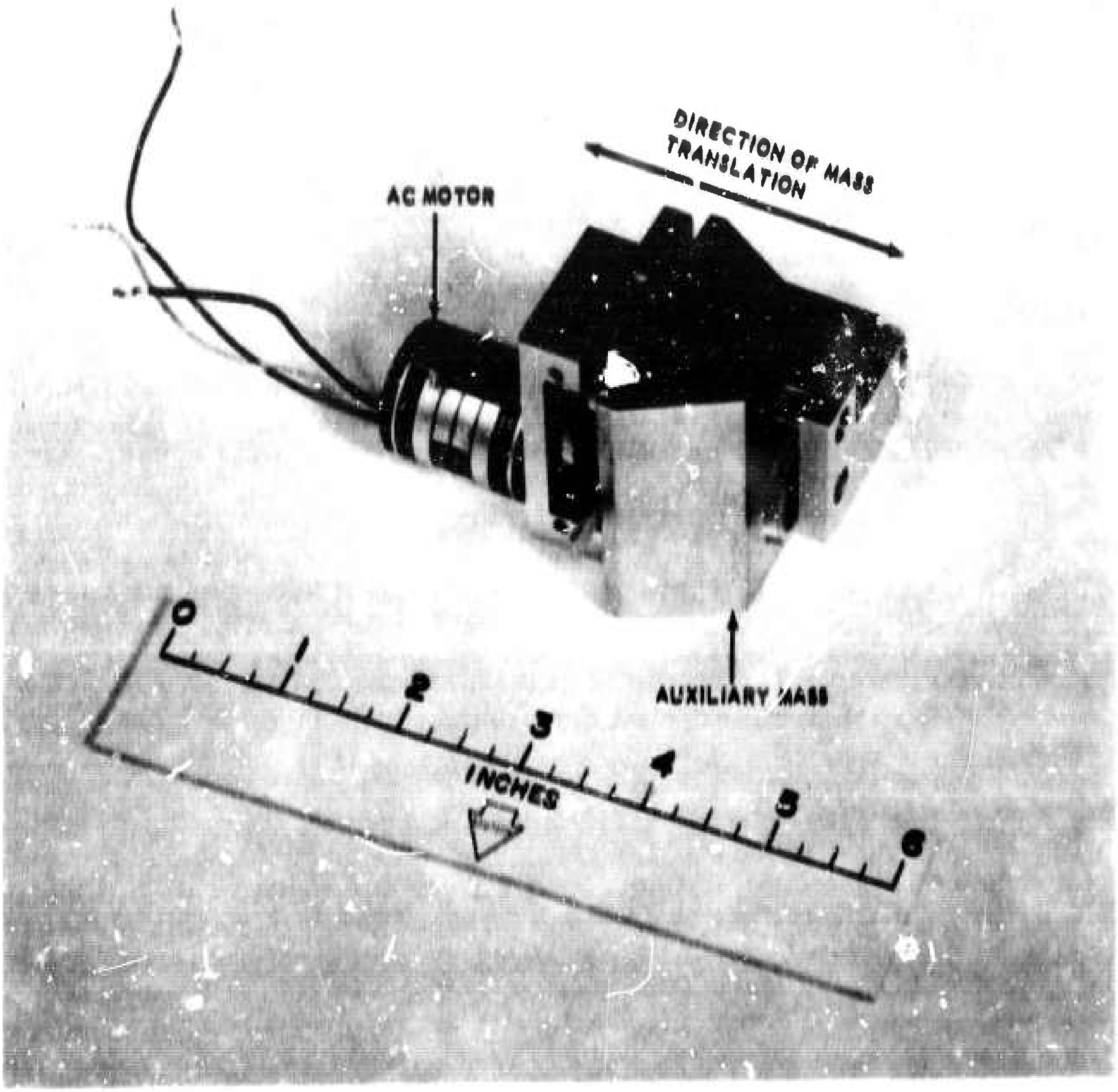

Figure 2. Mass positioning device for one module of the LP triaxial seismometer

G 3092

2.2.3 Period Adjust

The remotely operated period-adjust mechanism, shown in figure 3, is mounted on the instrument as illustrated in figure 1. The unit is a motor-driven device in which a force is applied to the adjustable lip of the triflexure assembly. The triflexure, which is the main pivot of the spring-mass system, is designed to provide a small positive restoring force to the spring system (consisting of the triflexure pivot, three crossflexures or Bendix pivots, and the helical coil spring). A tensile force on the adjustable lip of the triflexure decreases the internal loading of the triflexure and thereby increases the positive restoring force of the spring system. An increase in the overall restoring force shortens the module free period. The triflexure can be operated with compression forces on the adjustable lip, thus producing negative restoring forces, but for the purposes of the present design, only positive restoring forces are desired.

The seismometer module free period is adjustable from 10 to 25 seconds and the range can be covered in about 15 minutes of period-adjust motor operation. The remote change of module free period is not a linear time function since it is accomplished by changing the system restoring force. System restoring forces at the short periods are naturally greater and, therefore, require larger loads on the triflexure adjustable lip. Laboratory tests show that about 18 seconds of period-adjust motor operation are required to change the module free period from 25 to 24 seconds while about 2.5 minutes are required to change from 11 to 10 seconds. After minor modifications to reduce linkage inefficiencies, successful tests of one period-adjust mechanism were concluded. Construction of the two remaining mechanisms has been started with completion expected early in July 1967.

2.2.4 Mass Lock

Difficulties encountered during assembly of the first mass-locking mechanism indicated that some redesign would be required if acceptable reliability was to be obtained. The basic design concept has not been changed; the 10 kg mass is rigidly blocked and keyed to a pair of instrument stanchions; the instrument frame and magnet assembly is blocked with eccentric levers to a second pair of stanchions; and the quartz booms are shifted into a new position by eccentric cams that maintain the operational load upon the booms yet spring load the triflexure end to protect against damaging shock forces.

The redesign of the mass lock has been completed and has resulted in significant simplification of the mechanism. For instance, a number of solid shafts, gears, and bearings which were used to operate the various locking functions were replaced with flexible shafts. The mass-locking mechanism is still a paper design and has not been mocked up as a complete assembly. For this reason the effectiveness of the device has not been evaluated and

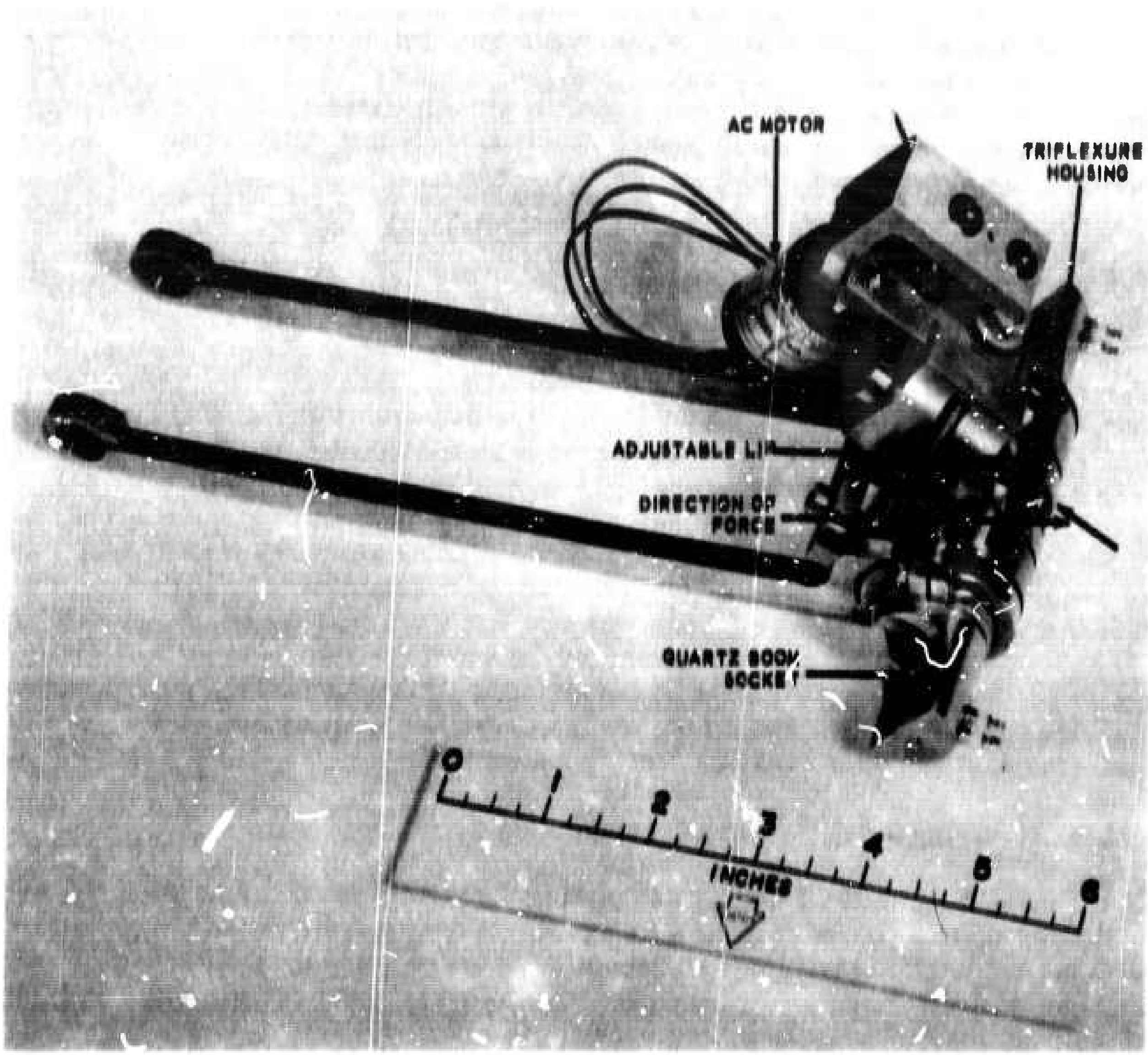

Figure 3. Period adjust mechanism for one module of the LP triaxial seismometer

G 3093

final specifications will be forthcoming. After tests are completed on the initial mass-locking mechanism, two additional units will be fabricated. It is expected that all of the locking assemblies will be available in August 1967.

3. PRELIMINARY TESTING OF THE LONG-PERIOD TRIAXIAL BOREHOLE SEISMOMETER, TASK 1c

3.1 GENERAL

Laboratory testing of the LP triaxial seismometer is essentially complete. Observations and measurement of its general characteristics have continued for several weeks. The seismometer has been operated in a low-gain seismograph system during much of this time.

3.2 SEISMOMETER

A number of specific tests have been made on the experimental seismometer. The results of a shake-table driven seismometer frequency response, the effect of temperature changes on mass position, and the effect of instrument tilt on the mass position and free period are reported in the following paragraphs.

The completion and installation of the mass-locking mechanism will allow the seismometer to be lowered into a 50 ft deep hole located at Geotech's Garland plant for further operational tests. The lowering sequence and subsequent operation of the seismometer in a seismograph system will provide desired handling experience before the field tests are started.

3.2.1 Frequency Response

Figure 4 shows the frequency response of the experimental Model 26310 seismometer. Tests were run with the seismometer free period set at 23.25 sec and at 16.45 sec. Apparently, anomolous data were obtained at frequencies lower than the resonant frequency of the instrument in that the slope of the response curve in this range deviates from the 18 dB/octave slope normally expected from standard rectilinear seismometers using velocity transducers.

The difficulty of making the shake-table test was relatively severe in the period range of 100 to 20 sec because of the high level of seismic noise at Geotech's Garland plant compared to the low level of the seismometer output. In order to improve the signal-to-noise ratio during the shake-table tests, a Krohn-Hite Model 330AR band-pass filter was used to attenuate the noise outside the band of interest. Since such a filter could conceivably modify the

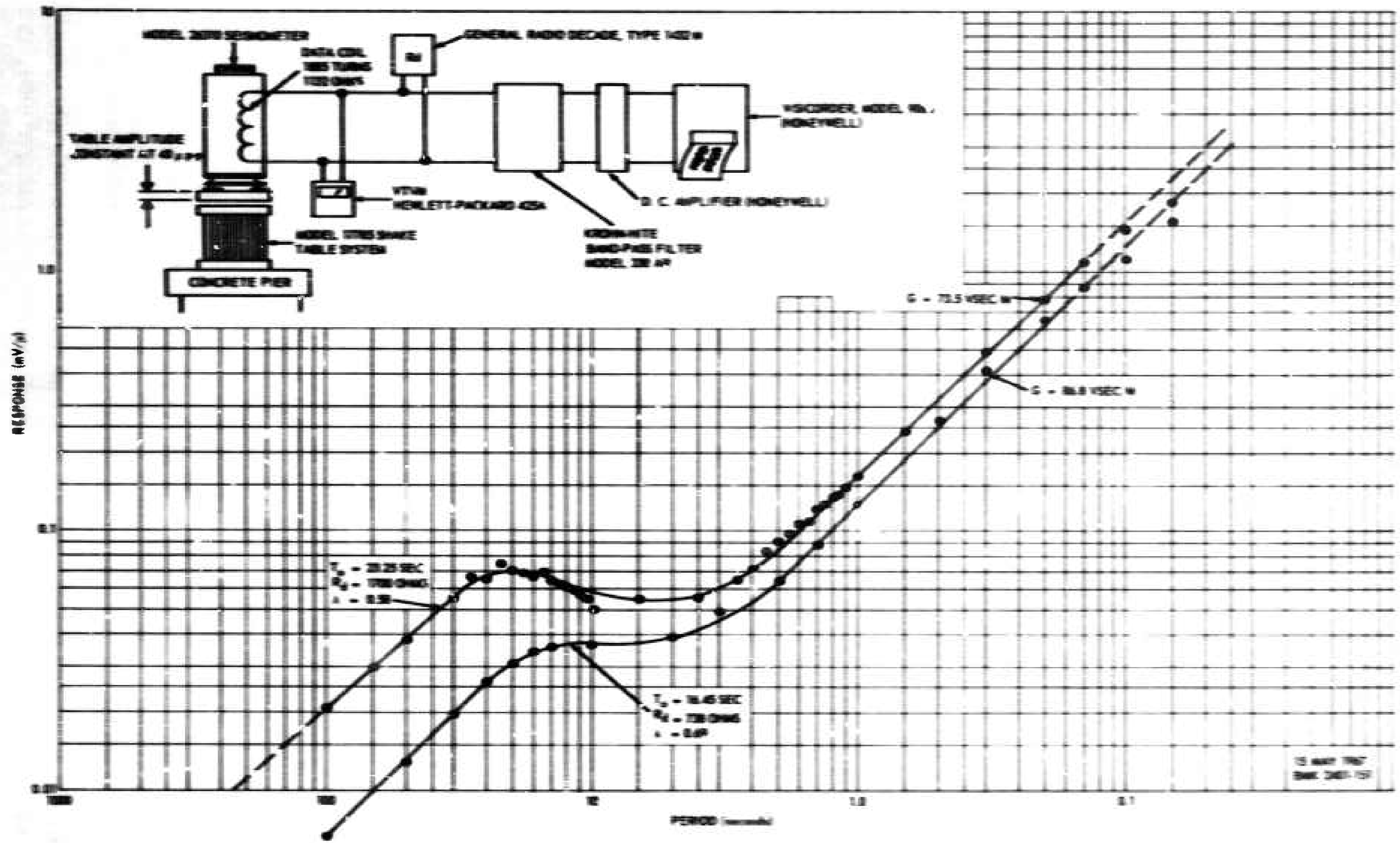

Figure 4. Frequency response constant amplitude input, [illegible] seismometer

G 3894

measured frequency response of the seismometer, observations were made at the extreme frequencies of interest with the filter both connected and disconnected. In this way, it was possible to adjust the pass band of the filter for a flat frequency response throughout the band of interest.

While it is possible that the test instrumentation and/or the manner in which the test was conducted led to the apparently anomolous results shown at the longer periods of figure 4, a more likely explanation appears to involve the geometry of the triaxial seismometer. Plans have been made to examine this possibility as well as preparation for additional shake-table tests. It should be recognized that a vertical shake table does not excite the mass of the triaxial seismometer to the same amplitude of a comparable vertical seismometer under the same test conditions. The mass of the triaxial seismometer is constrained to move along a line inclined at 54°44' to the vertical. This line is the sensitive or normal axis of the seismometer and only the component of mass motion along this axis is effective in generating a voltage as the coil moves relative to the magnetic structure. Thus, for a given vertical shake-table amplitude, the expected component of mass motion in the triaxial is 0.577 less (cos 54°44') than that of a vertical seismometer. This factor is important when comparing the shake-table derived frequency response of the triaxial to that obtained by driving the mass with the calibration coil located on the 54°44' inclined axis.

The generator constant (G) of the signal or data coil can be determined from the shake-table frequency response. The constant determined is the vertical component only and must be divided by 0.577 to provide the normal G obtained in calibration coil frequency response tests. The G determined in this manner from the T_o = 23.25 sec frequency response curve of figure 4 is 73.5 V sec/m and that from the T_o = 16.45 sec curve is 86.8 V sec/m. The 86.8 V sec/m value compares favorably to the 87.2 V sec/m as calculated from the coil dimensions and the magnetic flux level. The variation in the value of G at the longer period from that at the shorter is unexplained for the present. It should be pointed out that the value of G as shown in figure 4 is from the experimental coil. The final coil design will have a generator constant of 122 V sec/m.

3.2.2 Temperature Effects

It was reported in earlier reports that testing of the experimental seismometer element has revealed a tendency of the mass position to drift with temperature change. As temperature is decreased, the mass has been consistently observed to rise. This effect of temperature change on mass position can be referred to as a "negative" temperature characteristic. Early tests with the first engineering model seismometer element have also shown this negative temperature characteristic.

The magnitude of mass drift with temperature change is related to the free period of the seismometer. As the free period is increased, the amount of mass drift for a given temperature change increases. The average mass position change for the experimental module with a free period of 15.0 seconds, is 0.18 mm/°F. Although the magnitude of the mass drift with temperature change

is related to the free period of the seismometer, the ultimate source of the drift does not necessarily originate with the period-determining mechanism. However, additional effort to improve mass-position stability is planned since the suspension of the Model 26310 seismometer is designed for complete temperature compensation.

To date, there has been little success in finding the source of the negative temperature characteristic. A careful examination of the seismometer suspension and tilt-table system suggested that one possible source might be the manner in which the sensitive axis tilt-table drive motor was mounted. Changes in the design of the mount did not give the expected improvement.

Figures 5 and 6 show the results of five tests which were run using a brass, an aluminum, and a noncompensated motor mount. The failure of the aluminum motor mount of test No. 5 to complete the improvement suggested by the brass motor mount of test Nos. 1, 2, and 3 led to the conclusion that mass drift with temperature change could not be positively attributed to the sensitive axis tilt-table motor drive system.

Since the experimental and the first engineering model seismometer exhibit approximately the same negative temperature characteristic, it is very likely that the source of the mass drift with temperature change can be found. If the sign of the temperature characteristic had been opposite between the two elements thus far assembled, or if the sign is random among any of the elements to be assembled, the chances of finding the source of drift and improving the temperature characteristic will be poor. The probable source of the drift is suspected to be with an erroneously assumed coefficient of thermal expansion or thermal modulus of elasticity.

Even though a null temperature characteristic is desirable, it is unlikely to be obtained in practice, especially at the longer periods. Any mass drift with temperature change will increase as the period is increased. At its present state of development, the Model 26310 seismometer can be easily adjusted to desired parameters and, therefore, should be satisfactory with regards to its temperature characteristics.

Figure 7 shows the history of a 70 h continuous run of the experimental seismometer element made over a weekend at ambient room temperature. The total mass drift was 2.7 mm for a 15.2°F change in temperature with the seismometer free period of 15.0 sec. On two consecutive days of the run, the mass remained within 0.45 mm of its position through a 4.7°F change in temperature.

3.2.3 Tilt Effects

A series of tests showing the variation of the mass position and free period as a function of seismometer tilt in both the cross-axis and sensitive-axis planes were made at the request of the Project Officer. Figure 8 shows the setup used in the cross-axis tilt tests with the seismometer mounted on a

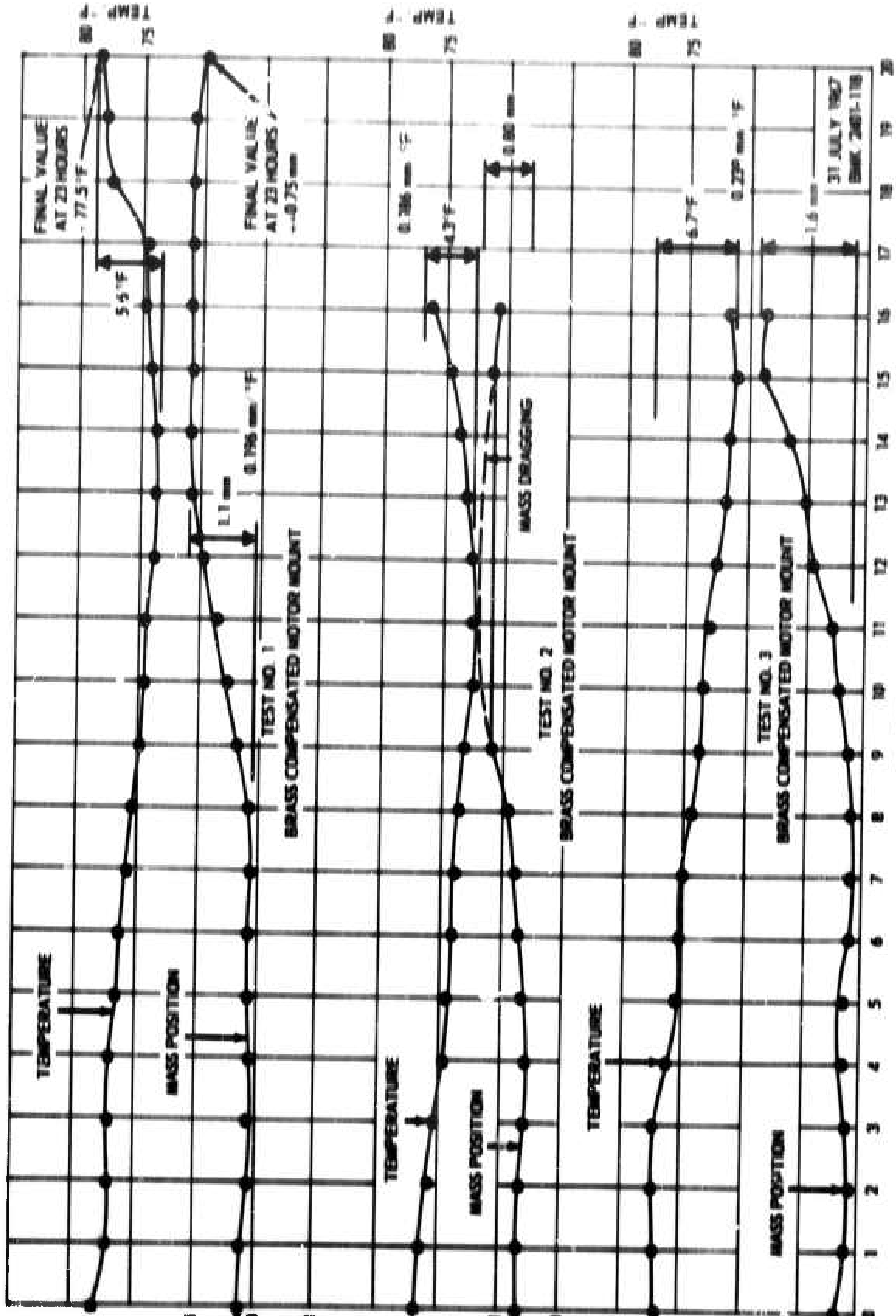

Figure 5. Temperature and mass position as a function of time, Model 2530 seismometer

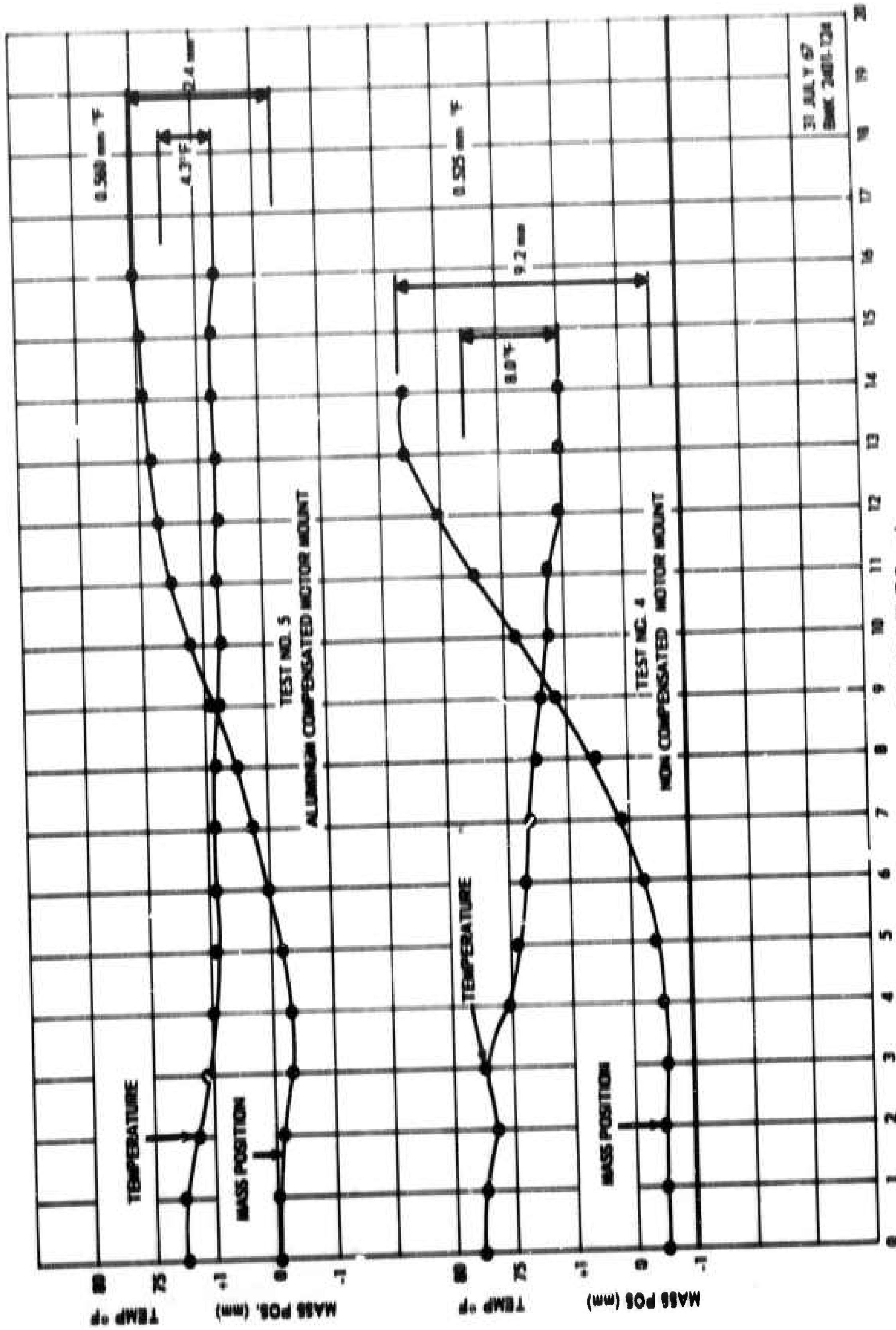

Figure 5. Temperature and mass position as a function of time, Model 26300 Seismometer

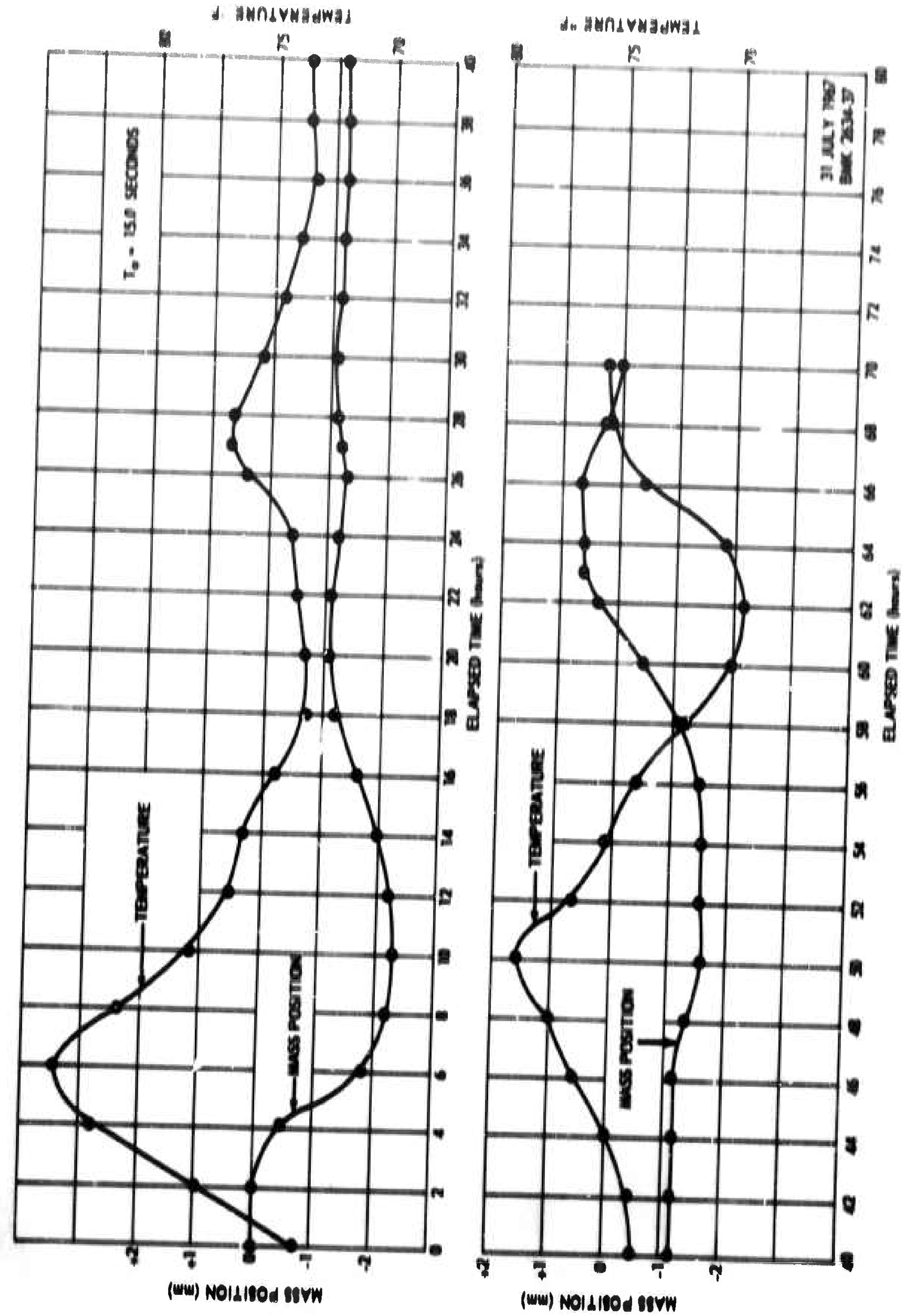

Figure 7. Temperature and mass position as a function of time, Model 2630 seismometer

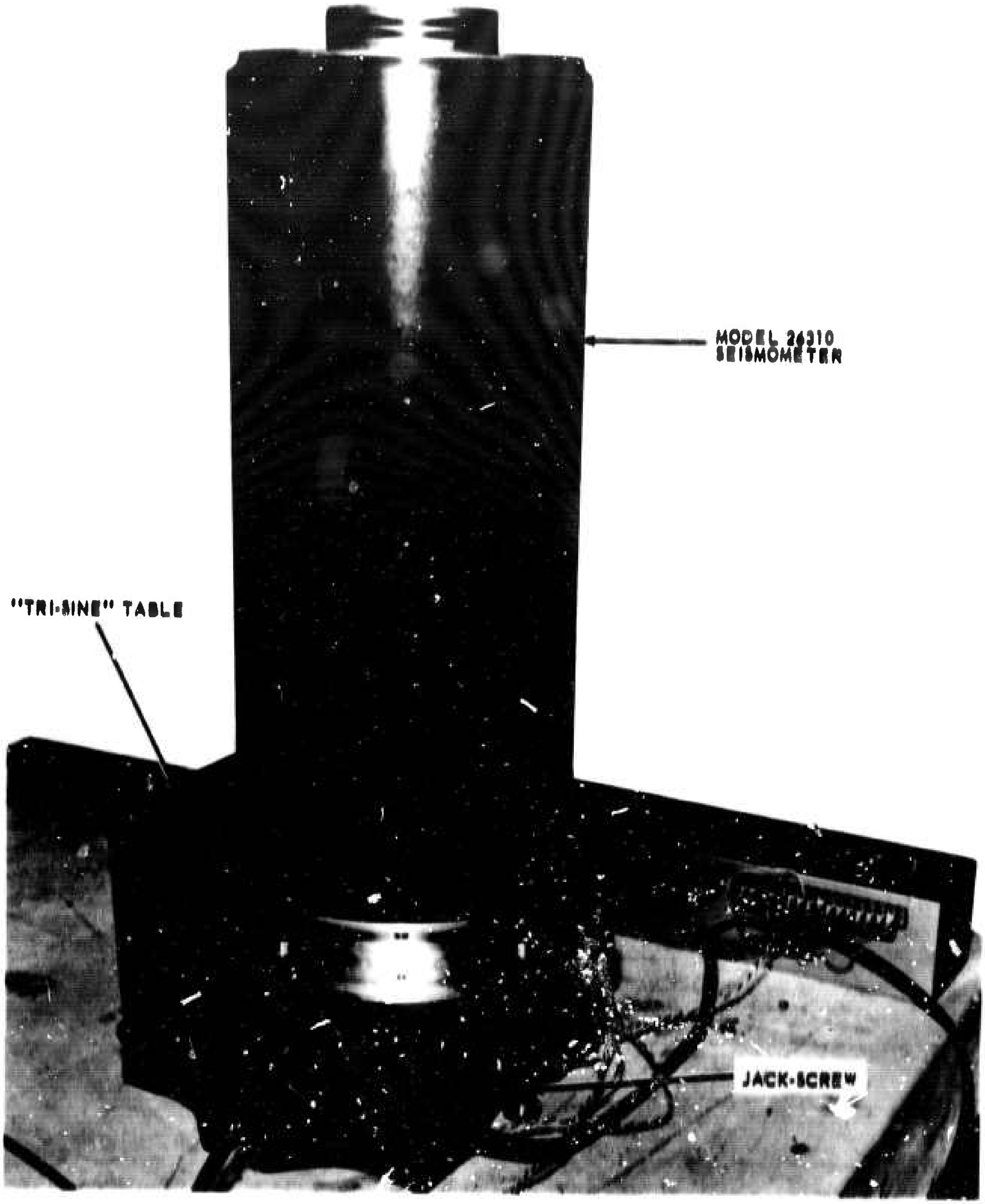

Figure 8. Test setup for cross-axis tilt tests, Model 26310 seismometer

G 2800

"tri-sine" table. Tilt was controlled by a jackscrew and measured by a sine bar and micrometer. A more delicate control of tilt was required for the tilt tests in the sensitive-axis plane. The extremely small tilt range of 120 arc sec necessitated the use of the Geotech Model 12760 tilt table.

Figures 9, 10, and 11 show the results of the tilt tests in the sensitive-axis plane. The tests were made with the seismometer adjusted to the natural periods of 10, 20, and 25 sec, respectively. An additional test in the sensitive-axis plane was made in which the mass was repositioned to center by an auxiliary mass adjustment. The results of this test are shown in figure 12.

A single test was made with the seismometer tilted in the cross-axis plane. The free period was adjusted to 20 sec for this test and the results are shown in figure 13.

The test results shown in figure 12 are generally predictable by considering the geometry of the instrument involved and the change in forces with tilt in the sensitive-axis plane. The results shown in figures 9, 10, 11, and 13 are only casually predictable and their significance requires an intimate knowledge of the instrument.

The tilt tests at the longer periods show a lack of "retrace" for the mass position and free period as tilt was returned from its maximum back to its reference or "zero" value. This lack of retrace could be expected (although its magnitude cannot be predicted) by considering the mechanical hysteresis of the elastic materials and the deformation of the seismometer components resulting from instrument tilt.

In order to get an idea of the significance of the tilt-test results, a search was made for comparative literature of other long-period seismometer tests either published or unpublished. The search was unable to locate any pertinent data. Apparently, tilt tests of the nature described above are not generally made on seismometers of the long-period range involved. The fact that the tests could be made on the Model 26310 seismometer is encouraging and may further confirm the stability of this instrument.

Figure 13 has a significance in addition to the tilt effects shown. In Quarterly Report No. 3, it was reported that the precision mercury switches used as tilt sensors in the cross-axis plane have a "dead" zone or a zone in which tilt is not sensed. The result of this dead zone causes the seismometer to have a tilt error in the cross-axis plane at the end of the tilt table leveling sequence. However, since the mercury switches are a simple and reliable means of controlling the cross-axis tilt motor they will be retained for the present. Figure 13 shows that the free period change as a function of cross-axis tilt is essentially flat. Thus, it may be expected that the free period will remain unchanged, for all practical purposes, as the seismometer is allowed to recover from cross-axis tilt errors under control of the mercury switches.

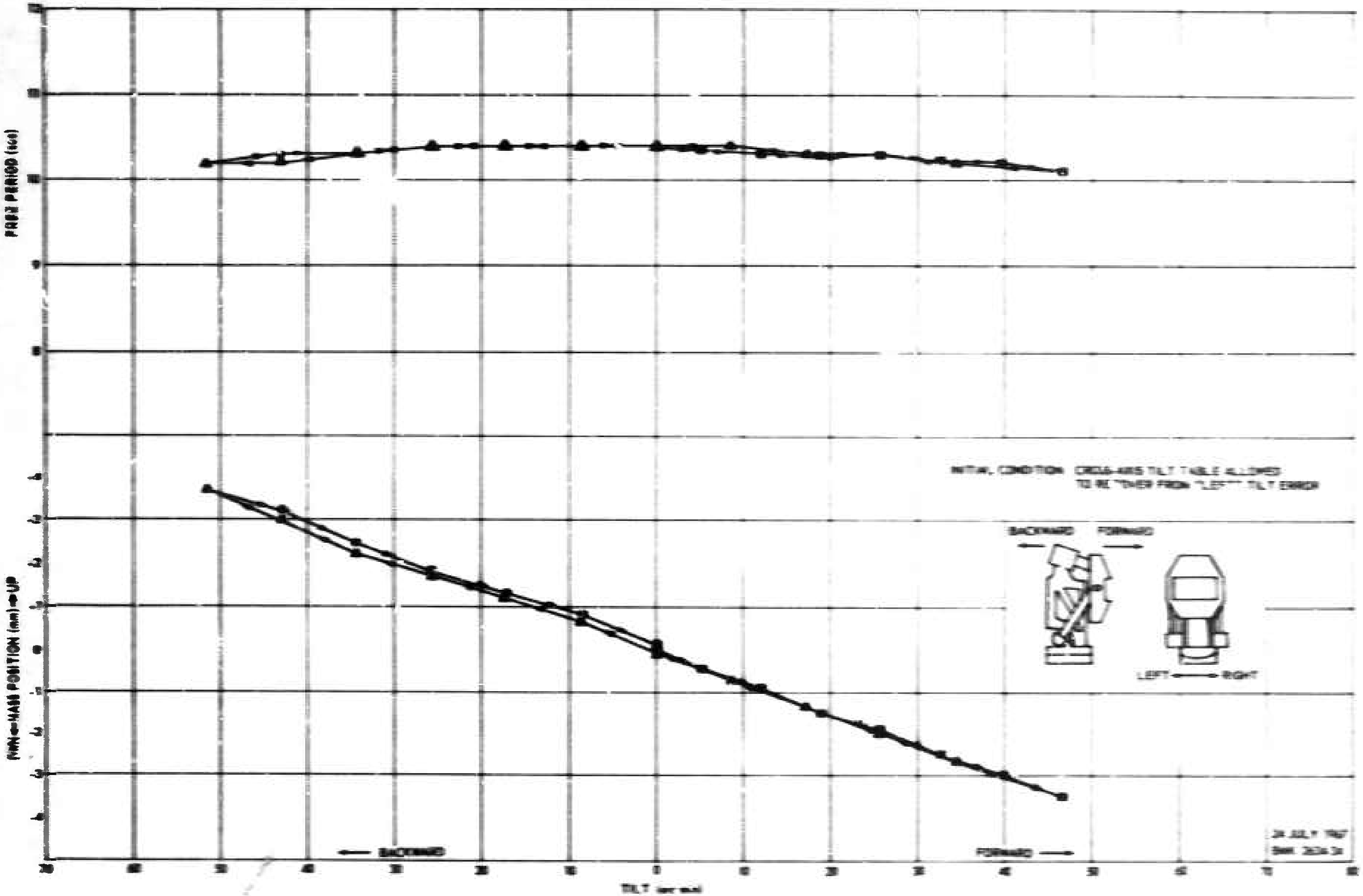

Figure 9. Free period and mass position as a function of sensitive axis tilt, Model 2[illegible] seismometer

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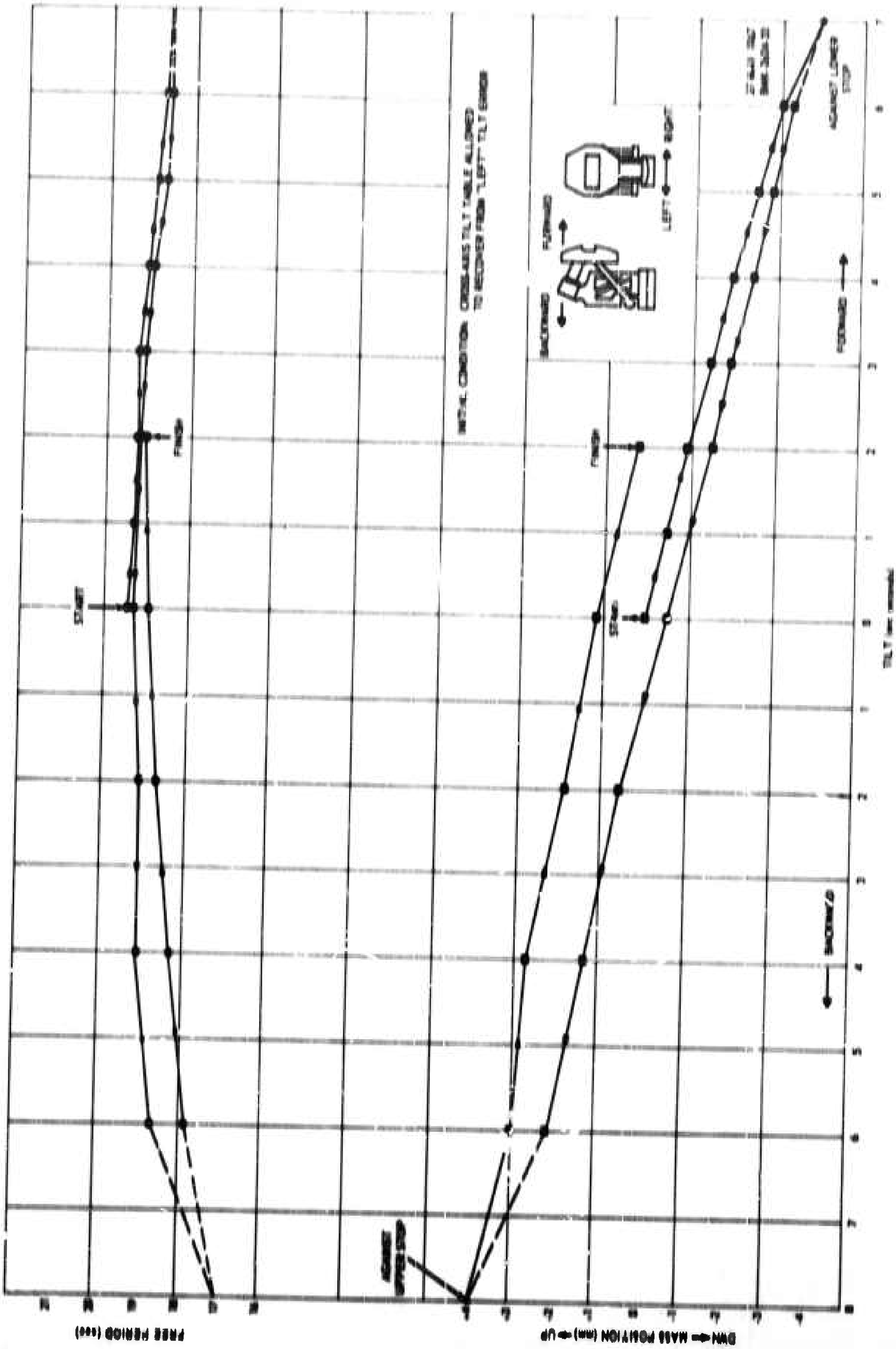

Figure 11. Free period and mass position as a function of sensitive axis tilt, Model 23300 seismometer

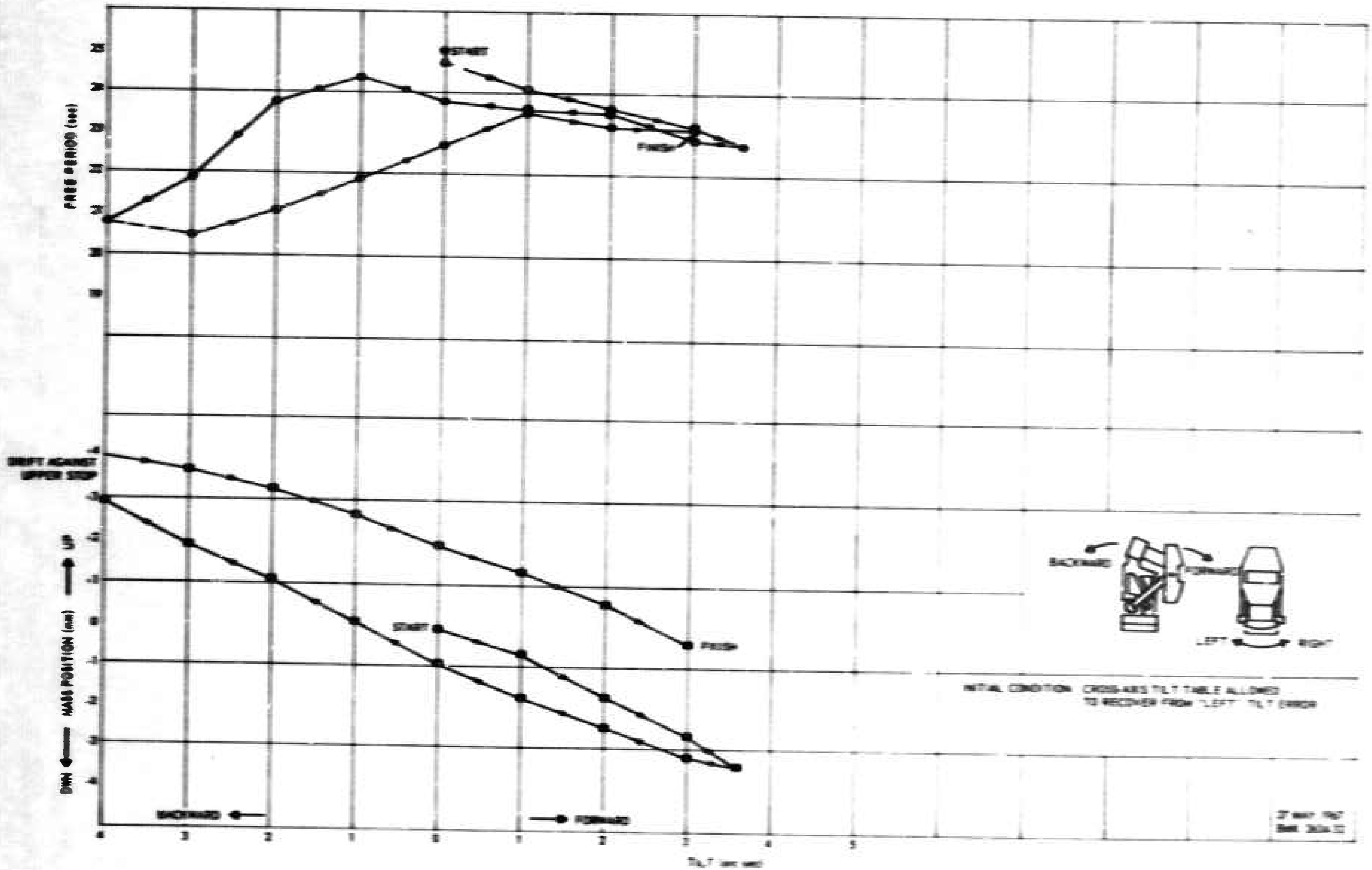

Figure 11. Free period and mass position as a function of sensitive axis tilt, Model 25300 seismometer

G 3108

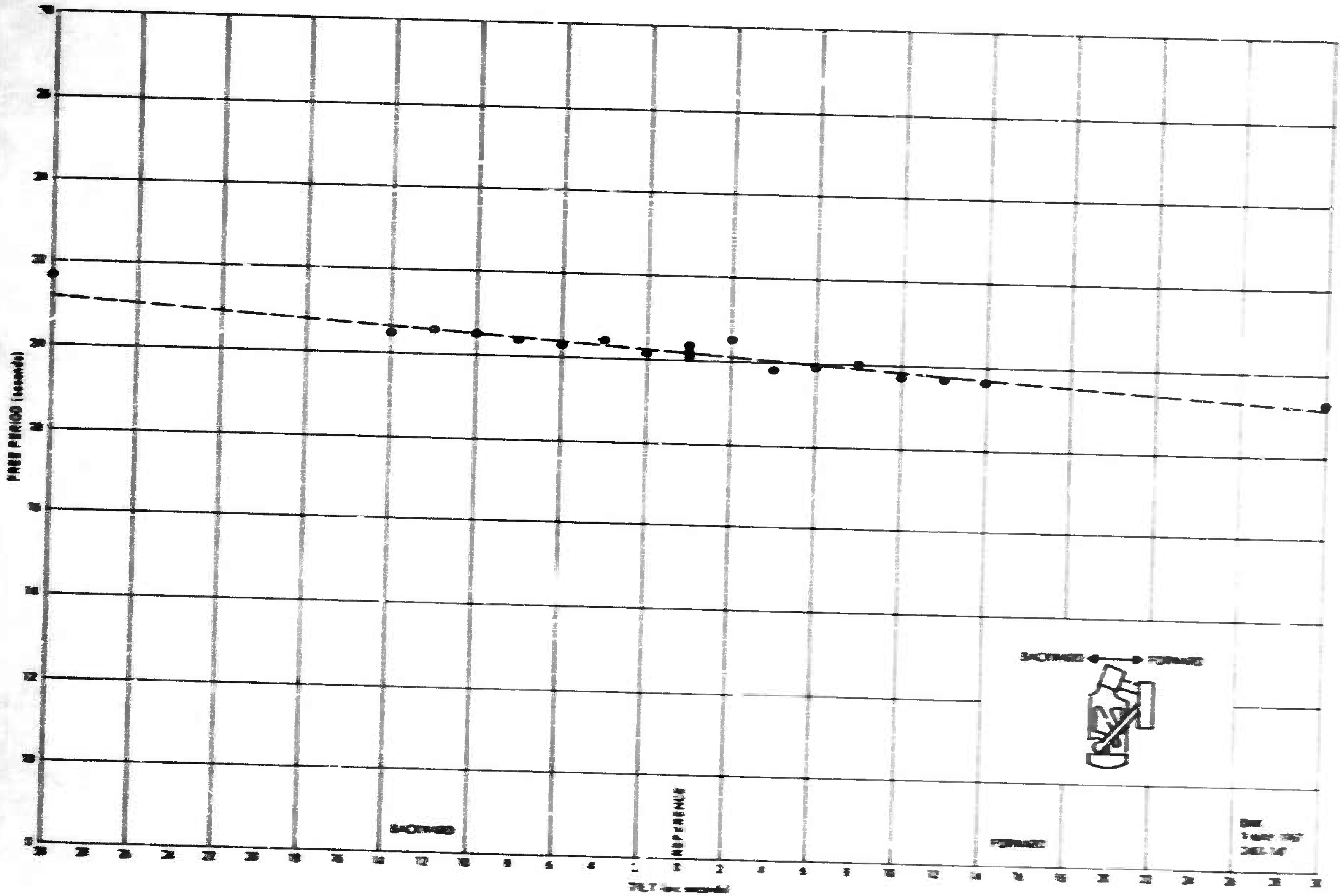

Figure 12. Free period as a function of tilt, mass held at "zero" by auxiliary mass adjustment, Model 2530 seismometer

G 3081

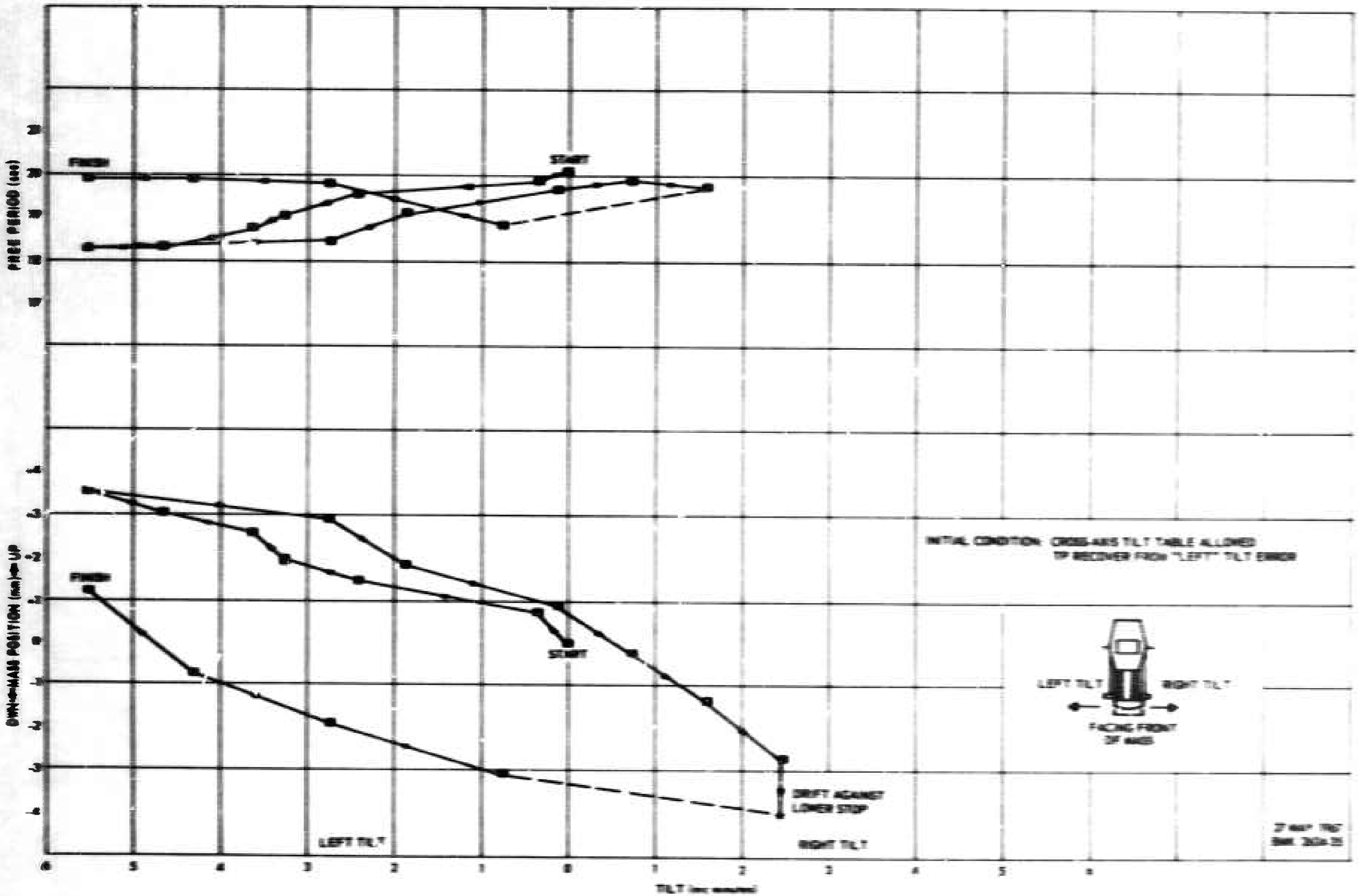

Figure 13. Free period and mass position as a function of cross axis tilt, Model 26310 seismometer

G 3982

3.3 INSTRUMENT CONTROLLER

Assembly of a tophole switching device, to actuate and control various circuits of the LP triaxial seismometer located downhole, is in progress. Unreasonably long delivery of three momentary contact switches has delayed the assembly and subsequent checkout of this unit. Because of this abnormal delay, plans have been made to substitute electrically equal and readily available switches mounted on subpanels.

3.4 ACCESSORY EQUIPMENT

3.4.1 Holelocks

The load supporting holelock is shown in figure 14 with its inner and outer cases removed. The inner case provides a moisture free environment for the operating mechanism when submerged in fluids up to 500 psi pressure. The outer case is for mechanical protection of the supporting arms. The holelock employs a motor driven Saginaw ball screw to extend and retract its two supporting arms. With the arms extended and engaged in a casing joint, the holelock supports the instrument weight and forces the seismometer package against the casing.

The stabilizing holelock is shown in figure 15. This device extends a pair of plungers which engage the casing at two points in the horizontal plane 120° apart. When the plungers engage the casing, a stationary shoe attached to the outer case of the stabilizing holelock is forced into contact with the casing. It has been suggested that this support is necessary to provide intimate contact between the seismometer and the casing and thus ensure acceptable earth coupling. O-ring seals have been employed at all case openings to provide a watertight assembly at the design operating pressure of 500 psi.

3.4.2 Cables and Connectors

When no suitable waterproof electrical connector could be located, Geotech designed and built the connector shown in figure 16. The physical size of existing 48 pin connectors were considered prohibitive. The connector provides 55 electrical contacts, an anchor for the cable's center strain member, and effective moisture sealing at an external pressure of 500 psi.

The signal and control cable used to electrically connect the instrument to the surface is a specially fabricated cable having 4 shielded and 40 unshielded pairs of No. 24 AWG copperweld conductors. A steel strain member with a 500 lb breaking limit is located in the cable center for support of the cable only. The cable is rubber filled and has a vinyl outer jacket.

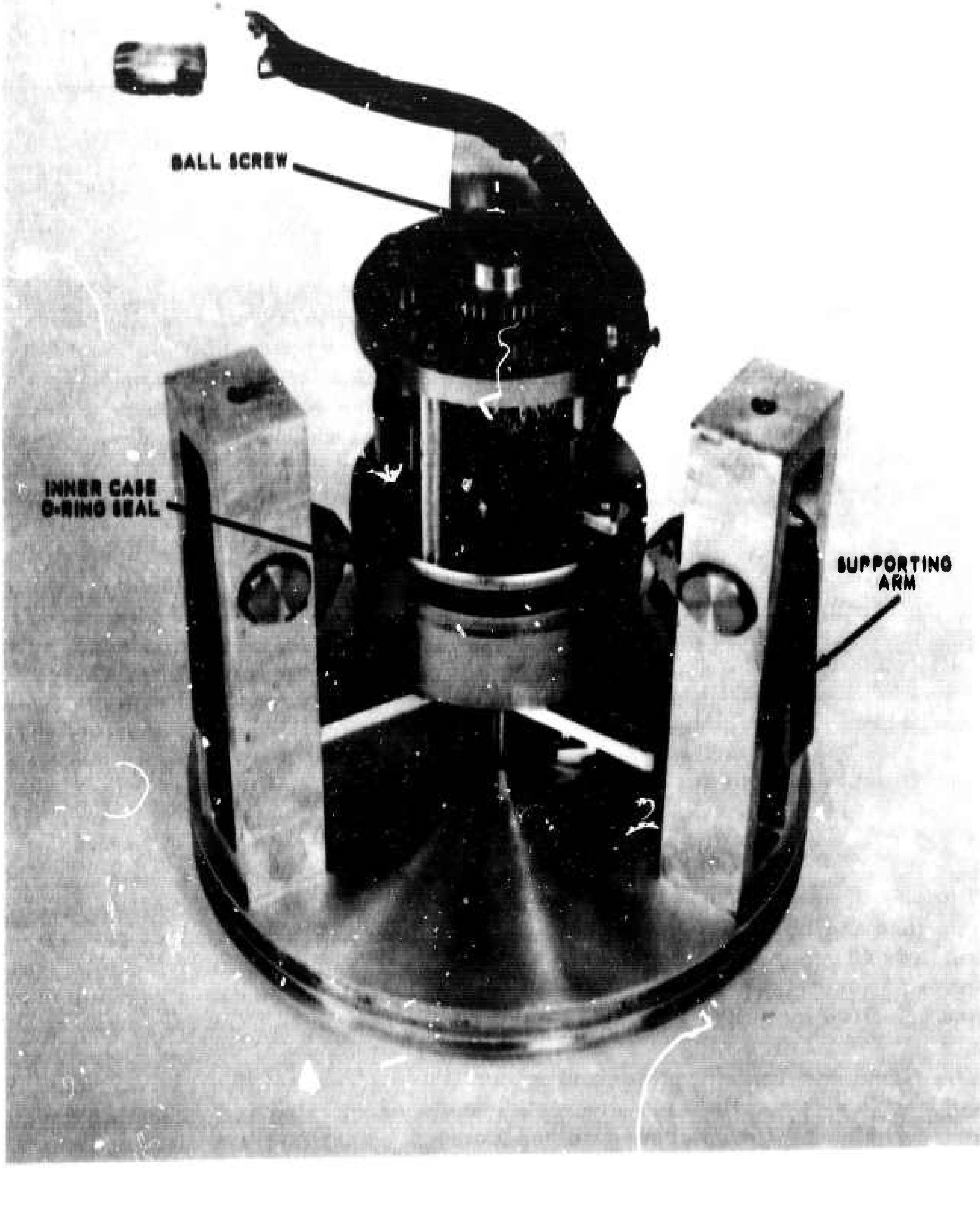

Figure 14. Load supporting holelock used at the lower end of the LP triaxial seismometer

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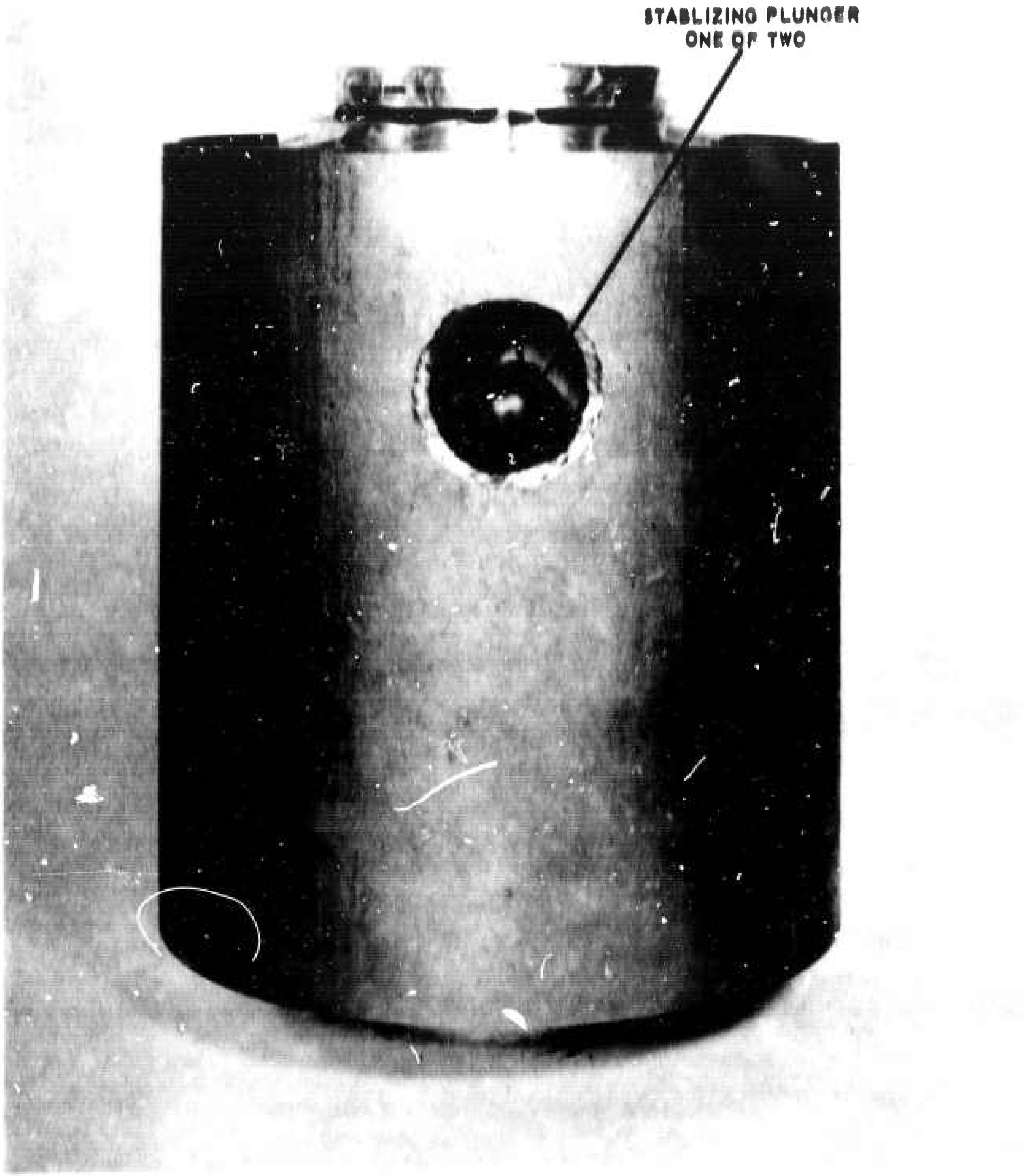

Figure 15. Stabilizing holelock used at the upper end of the LP triaxial seismometer

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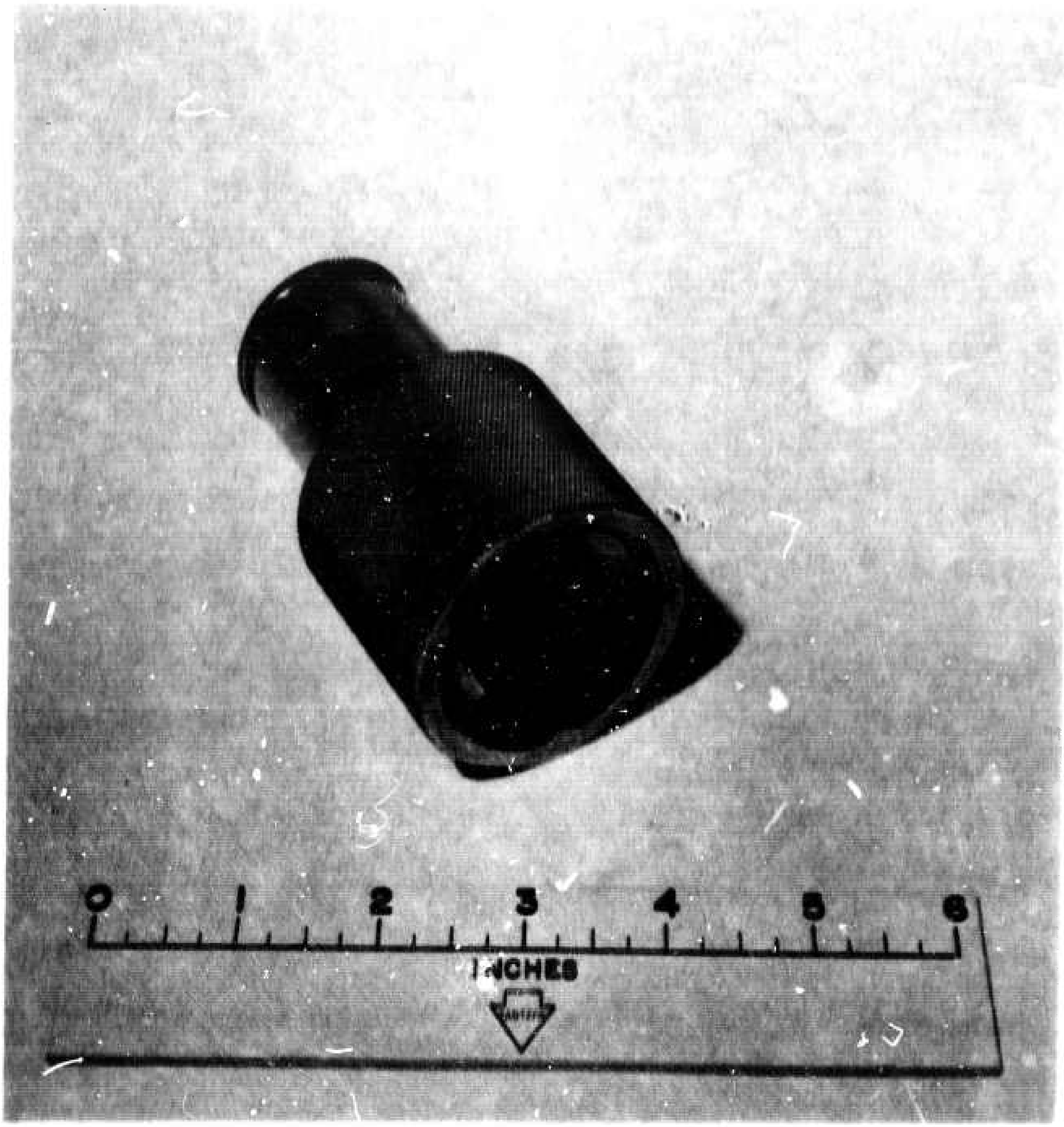

Figure 16. Special connector required for electrical connection of the LP triaxial seismometer to the multiconductor cable

G 3108

3.4.3 Installation Equipment

Azimuthal orientation of the triaxial seismometer is considered of major importance. To provide this orientation at initial installation and to permit further adjustments during field testing, special installation devices must be used. These devices are shown in figures 17 and 18. The stinger of figure 17 is also shown in figure 1 attached to the instrument package.

The overshot, shown in figure 17, engages the stinger for positioning the seismometer. To engage the stinger, the overshot is lowered until it makes contact. It is then allowed to rotate counterclockwise until it "bottoms." The overshot is then lifted straight up to lock it on the stinger.

To disengage the stinger, the overshot must be lowered slightly (about 3/4 in.) and then rotated at least 45° clockwise (viewing from above). It can then be lifted clear of the stinger.

The overshot is positioned by means of a string of 10 ft long sections of seamless mechanical steel tubing. The ends of the tubing sections, as well as the overshot, are fitted with keyed joints as shown in figure 18. The instrument is lowered or raised in 10 ft increments as lengths of tubing are added or removed. The overshot and the tubing string are disengaged from the seismometer after the instrument is securely located in the hole. The tubing string is completely removed from the hole during operation and must be reattached to the instrument when relocation or removal of the seismometer is necessary.

The instrument is raised or lowered by means of a 1-ton capacity electric chain hoist suspended from a 20 ft tripod centered over the hole. The signal cable is spooled in or out of the hole by a small electrically driven winch at the same rate the chain hoist lowers or raises the seismometer.

4. FIELD MEASUREMENTS WITH THE LONG-PERIOD TRIAXIAL BOREHOLE SEISMOMETER, TASK 1d

Field measurements to collect and analyze long-period data to determine signal and noise characteristics in a shallow hole at the Uinta Basin Seismological Observatory is expected to begin the first part of October 1967. This evaluation will be concentrated upon a performance comparison of the triaxial seismometer with the conventional advanced long-period seismometers.

A schedule for the completion of work under Project VELA T/6706 is shown in figure 19. The schedule reflects the dates for work on existing tasks as well as the dates for proposed work under Task 1e.

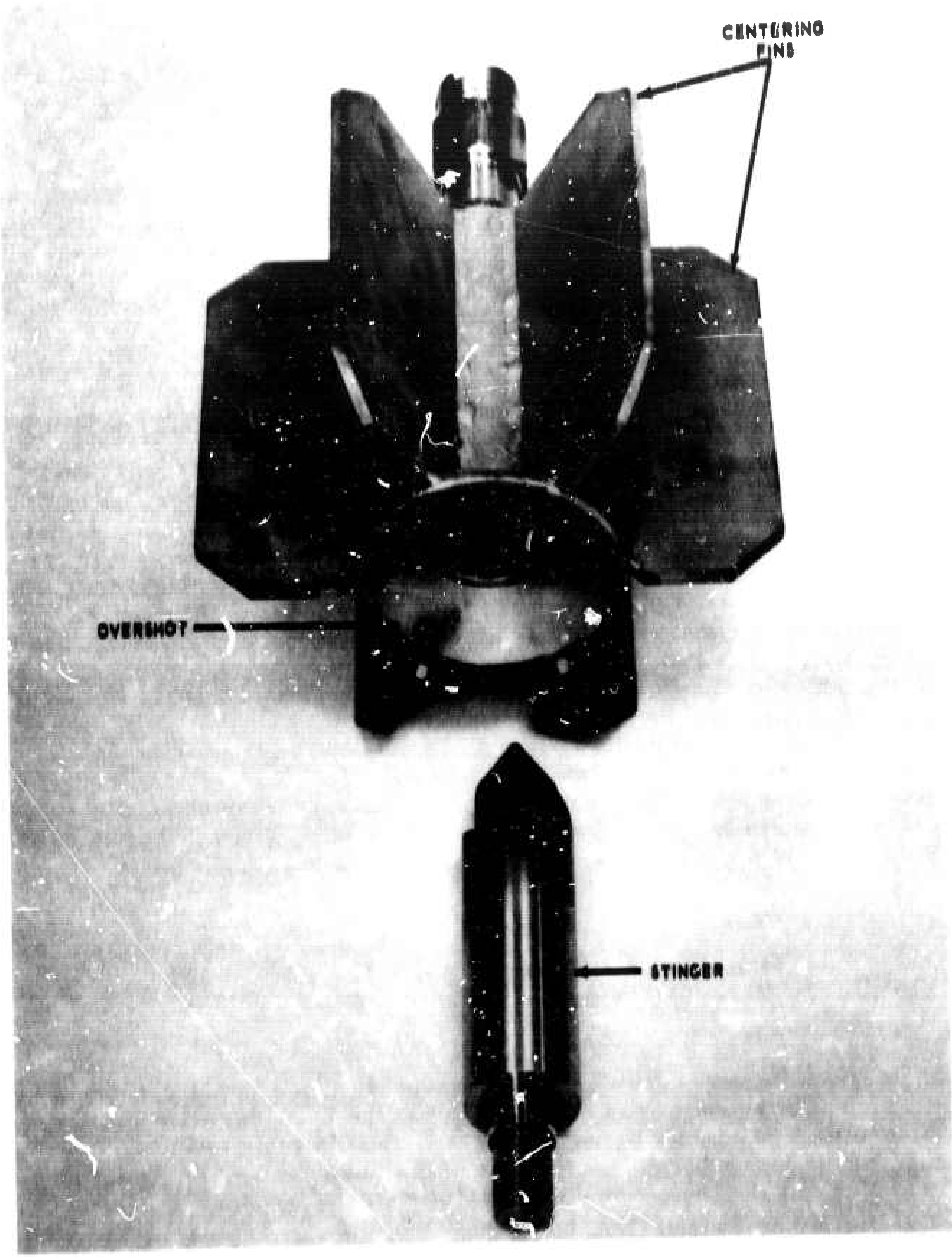

Figure 17. Stinger and overshot used to install and remove the LP triaxial seismometer

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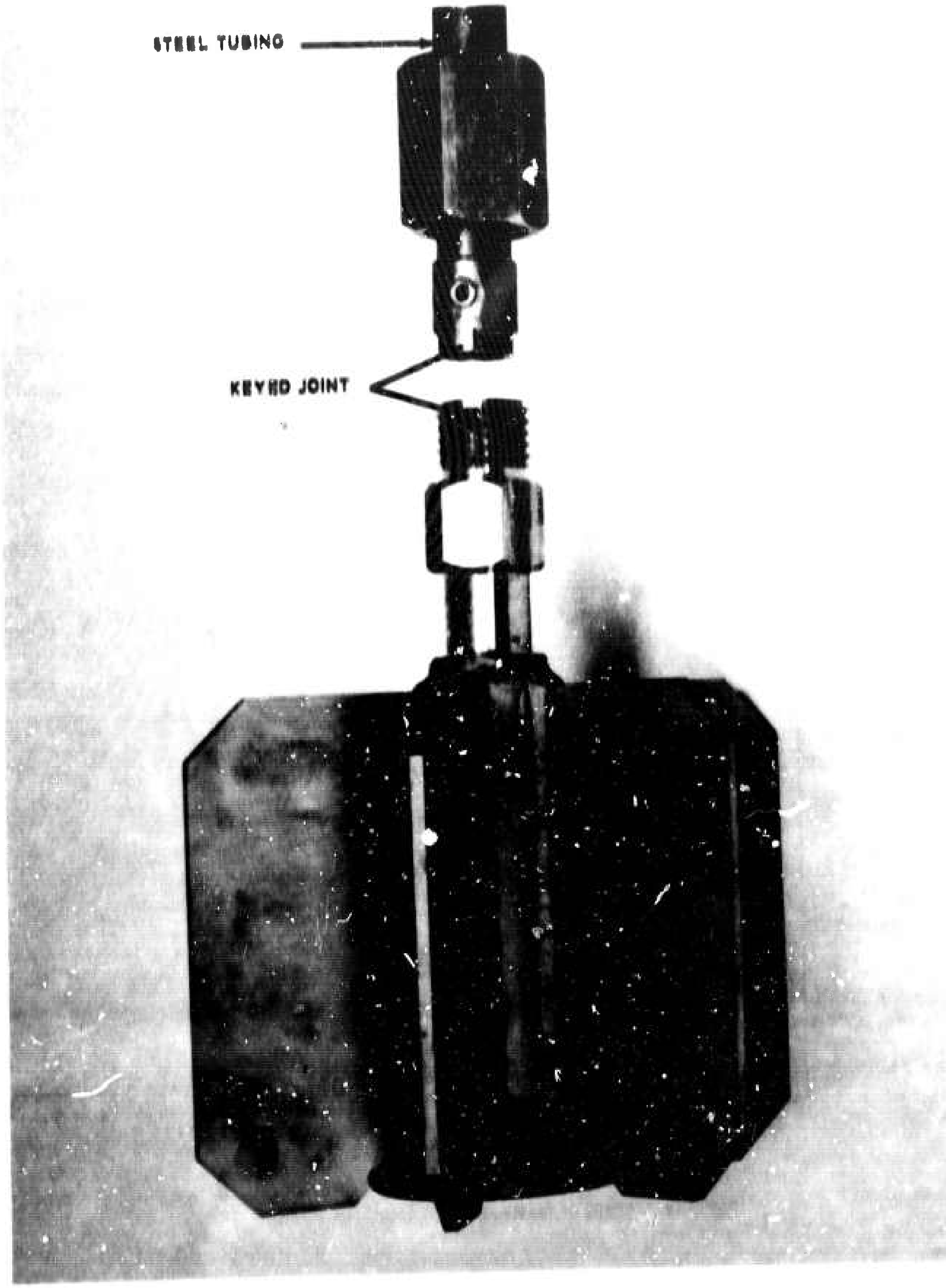

Figure 18. Keyed couplings for maintaining orientation of the LP triaxial seismometer

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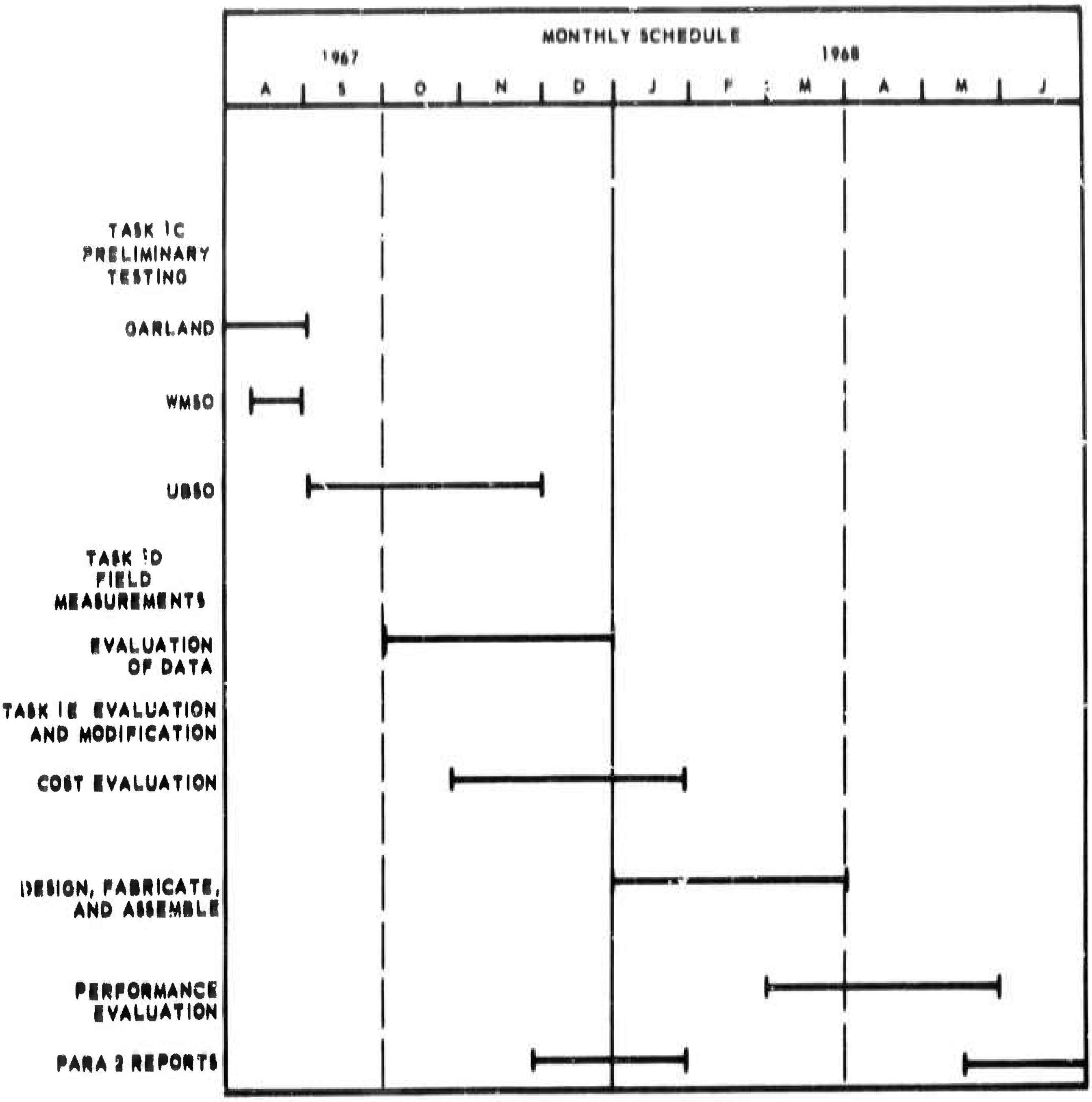

Figure 19. Schedule for completion of work under Project VELA T/6706

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APPENDIX to TECHNICAL REPORT NO. 67-51

STATEMENT OF WORK TO BE DONE

EXHIBIT "A"

STATEMENT OF WORK TO BE DONE

AFTAC Project Authorization No. VELA T/6706

1 - MAR 1966

1. Tasks:

a. Experimental Investigation of Thermal Noise. Continue the experimental investigation, defined in Project VT/072, of thermal noise components in seismograph systems, using torsional pendulums and associated equipment available from that project. Determine experimentally the spectral distributions of thermal noise in seismograph systems and compare the experimental results with theoretical predictions, as those derived by the National Bureau of Standards, for example. Provide data and methods for determining the ultimate possible magnification of a seismograph. Work on this task is to be completed within 4 months of the initial authorization date.

b. Development of a Long-Period Triaxial Borehole Seismometer. Modify the "Melton" long-period triaxial seismometer developed under Project VT/072 to adapt it for routine operation in shallow (200-foot) boreholes. Reduce the seismometer's diameter so it will fit inside standard 13.375-inch outside diameter shallow-well casing. Develop and add a suitable level sensor and remotely-controlled levelling device.

c. Preliminary Testing of the Long-Period Triaxial Borehole Seismometer. Prepare a cased, shallow borehole at a VELA seismological observatory to be designated by the AFTAC project officer. Assemble handling equipment for installing the seismometer. Conduct preliminary tests of the modified instrument in the test hole to determine its stability and the effects of temperature and local tilting as functions of depth. Through the use of improved installation techniques, selective filtering, design improvement or other means, develop a method for operating the seismometer so that magnification in the 10 to 100 sec period band is limited only by propagating seismic noise.

d. Field Measurements with the Long-Period Triaxial Borehole Seismometer. Collect and analyze data to determine long-period signal and noise characteristics in shallow boreholes, to identify principal long-period seismic noise components, to ascertain depth-environmental effects, and to compare the performance of the triaxial borehole seismometer with standard long-period seismometers.

2. Data Requirements: Provide report as specified by DD Form 1423, with Attachment 1 thereto.

AF 33(657)-16406

Attachment 1 to DD Form 1423
REPORTS
AFTAC Project Authorization No. VELA T/6706

1. General: Provide monthly, quarterly, final, and special reports in accordance with sentence 1, paragraph 1 of Data Item S-17-12.0, AFSCM 310-1; however, if that data item conflicts with the instructions of paragraph 2 below, the latter will take precedence.

2. Reports:

a. Monthly Status Reports. A monthly letter-type status report in 16 copies, summarizing work for the calendar month, will be submitted to AFTAC by the 5th day of the following month. Each report will be identified by the data listed in paragraph 2e and will include, but not be limited to, the following subject areas:

(1) Technical Status. Include accomplishments, problems encountered, future plans, actions required by the government, and appropriate illustrations and photographs.

(2) Financial Status. The contractor will follow the provisions of Data Item A-15-17.0, AFSCM 310-1A (Cost Planning and Appraisal Unit), in submitting financial data.

For the last month of each report period covered by a quarterly progress report, the monthly status report need include only the financial information.

b. Quarterly Progress Reports. Quarterly progress reports in 50 copies, summarizing work for 3-month periods, will be submitted to AFTAC within 15 days after the close of each such period. Each report will be identified by the data listed in paragraph 2e and will include the notices listed in paragraph 2f. Each report will present a precise and factual discussion of the technical findings and accomplishments for the entire report period, using a format similar to that of the final reports under Contract AF 33(657)-9967, as well as the technical information ordinarily required in the monthly reports.

c. Final Reports. The final report on Task 1a will be submitted in 50 copies to AFTAC within 60 days after work on that project is completed; the final report on the remaining tasks will be submitted in 50 copies within 60 days after the completion of all work. Each report will be identified by the data listed in paragraph 2e and will include the notices listed in paragraph 2f. Each report will present a complete and factual discussion of the technical findings and accomplishments of the project tasks, using the quarterly-report format.

d. Special Reports.

(1) Special reports of major events will be forwarded by telephone, telegraph, or separate letter as they occur and should be included in the

following monthly report. Specific items are to include, but are not restricted to program delays, program breakthroughs, and changes in funding requirements.

(2) Special technical reports may be required for instrument evaluations, project recommendations, and special studies when it is more desirable to have these items reported separately from the quarterly or final reports. Specific format, content, number of copies, and due dates will be furnished by this headquarters.

(3) All seismograms and operating logs, including pertinent information concerning time, date, type of instruments, magnification, etc., will be provided when requested by the AFTAC project officer.

e. Identification Data. All monthly, quarterly, and final reports will be identified by the following data:

AFTAC Project No. VELA T/6706.

Project Title.

ARPA Order No. 624.

ARPA Program Code No. 6F10.

Name of Contractor.

Contract Number.

Effective Date of Contract.

Amount of Contract.

Name and phone number of Project Manager, Scientist, or Engineer.

f. Notices.

(1) All quarterly and final reports will include the following notices on the cover and first page or title page:

Sponsored by
Advanced Research Projects Agency
Nuclear Test Detection Office
ARPA Order No. 624

Qualified users may request copies of this document from:

Defense Documentation Center
Cameron Station
Alexandria, Virginia 22341

This research was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, under the VELA-UNIFORM Program and was accomplished under the technical direction of the Air Force Technical Applications Center under contract AF 33(657)-16406.

(2) All quarterly and final reports will include a copy of DD Form 1473, Document Control Data - R&D (Reference AFR 80-29). AFTAC will designate the appropriate Availability/Limitations Notice for use on those forms.

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UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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3401 Shiloh Road
Garland, Texas

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2b. GROUP

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LONG-PERIOD SEISMOGRAPH DEVELOPMENT

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9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Qualified requesters may obtain copies of this report from DDC

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
HQ USAF (AFTAC/VELA
Seismological Center)
Washington, D. C. 20333

13. ABSTRACT

Development of the long-period triaxial seismometer and laboratory testing of its characteristics is essentially complete. Manufacturing changes in the mass-lock and period-adjust mechanisms are required before they can be assembled on the seismometer for laboratory and field tests of the instrument. Shake-table frequency response, the effect of temperature changes on mass position, and the effect of instrument tilt on the mass position and free period are reported.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Long-period borehole seismometer						
VT/6706						

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